Green Lake Water Quality

Monitoring Results
for Water Year 2012 at Green Lake

Green Lake *Photo by Sally Abella*

Prepared for the City of Seattle
by the King County Lakes and Streams Monitoring Group
Science and Technical Support Section,
Water and Land Resources Division
King County Department of Natural Resources and Parks

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Overview

The King County Lakes and Streams Monitoring Group and its predecessor the Lake Stewardship Program have worked with volunteer monitors on Green Lake since 2005 to track water quality, which has been of particular interest after the alum treatment of the lake was carried out in 2004 to control phosphorus concentrations in the water column. Volunteers undergo training and use equipment owned and maintained by King County. An example of the volunteer training manual is available on-line at http://www.kingcounty.gov/environment/waterandland/lakes/documents/manual.aspx

Two water quality sampling stations in the lake were established in 2005 and measurements were taken at both sites in the years 2005 – 2008. Beginning in 2009 and continuing through 2012, only one station was monitored for water quality, as the two stations had produced very similar results in the previous years. However, some year-round physical monitoring occurred at the fishing dock at East Green Lake (Figure 1), carried out by students from Billings Middle School under the supervision of their teachers.

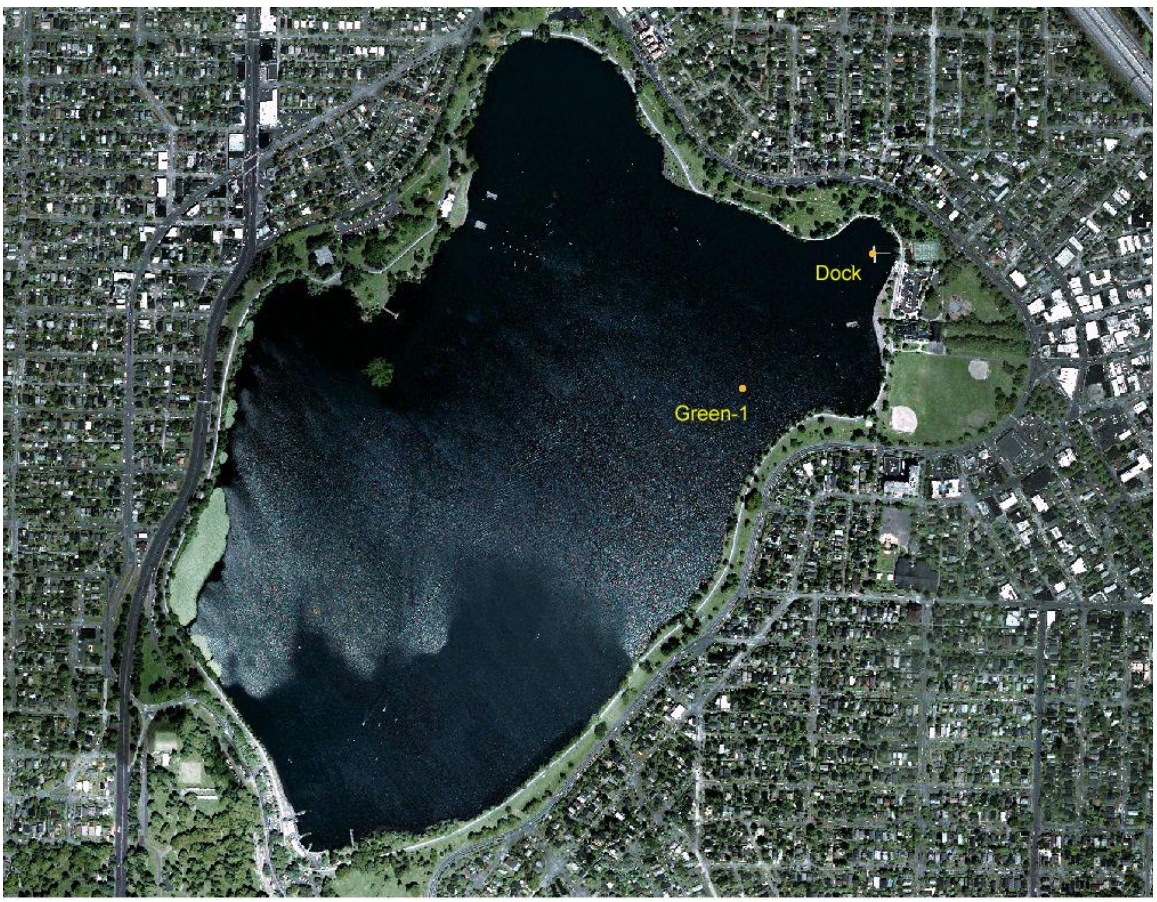

Figure 1. Green Lake Station locations

Green Lake is surrounded by a public park, and car-top boats can be launched at various points around the lake. It has a history of milfoil infestation, for which control efforts have been undertaken from time to time.

Green Lake has also been closed to recreation for bluegreen algae (cyanobacteria) accumulations and blooms several times, including during fall of 2012, described later in this document.

The lake has been treated with alum to reduce available phosphorus for algae control in 1991 and again in 2004. The most recent treatment reduced nutrients and immediately improved the water quality of the lake. The 2012 data indicate that Green Lake as a whole continues to have low to moderate algal productivity (lower mesotrophic, see definition below) with good water quality. Information from the current monitoring project is used to assess the longevity of the alum treatment's effect.

This report refers to two common measures used to predict water quality in lakes: the Trophic State Index or TSI (Carlson 1977), and the nitrogen to phosphorus ratio (N:P). The TSI and N:P ratios are calculated from the data collected through the volunteer monitoring program. TSI values are derived by a correlation that relates measured values of several parameters such as total phosphorus, chlorophyll *a* and Secchi transparency to estimated algal biovolume, indexing the estimated biovolume to a set indicator range of 0 to 100. Oligotrophic lakes, which have small amounts of algae (low productivity) and are generally characterized by clear water, have trophic state indicator values below 40. Eutrophic lakes, which have large amounts of algae (high productivity) and are generally characterized by less clear water due to the algae, have trophic state indicator values over 50. Between 40 and 50 are the mesotrophic lakes, with moderate amounts of algae and water clarity.

These numbers can be used to compare water quality over time and between lakes. While data should be collected over a longer term at Green Lake to verify trends statistically, it appears that productivity in the lake is currently stable or even slightly decreasing over the short term.

The discussion in this report focuses on the 2012 water year, which runs from October 2011 through September 2012, with the addition of two water quality sample dates in October 2012 as the water cools, and compares it to past years using the TSI indicators. Specific data used to generate the charts in this report can be downloaded from the King County Lakes and Streams Monitoring data website at:

http://your.kingcounty.gov/dnrp/wlr/water-resources/small-lakes/data/LakePage.aspx?SiteID=15

Data can also be provided in the form of excel files upon request.

Physical Parameters

The students from Billings Middle School under supervision of their teachers collected water level data from the dock at East Green Lake throughout the year (see map in Figure 1). Their precipitation data is collected from a rain gauge located at their school, which is not far from the lake. Volunteer monitors also collected Secchi transparency and temperature data from early May through late October at the lake station Green-1 (over the deepest part of the lake) as part of their sampling routine.

Good precipitation and water level records were compiled for the 2012 water year. There is a small amount of variation in the water level of the lake through the year, which often, but not always, matches the precipitation record (Figure 2). This is because both stormwater inputs and the water level in Green Lake are managed by Seattle Parks Department and Seattle Public Utilities to maximize water quality and recreational opportunities. However, a prolonged period of drought, such as occurred in late summer / fall of 2012, will result in a decline in water levels in the lake.

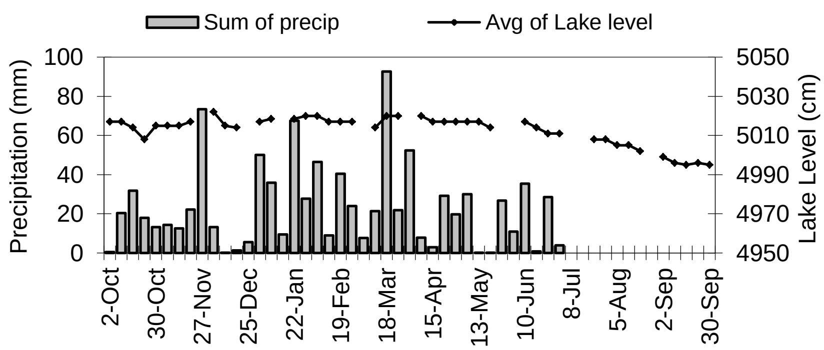

Figure 2: Green Lake Water Level and Precipitation WY 2012

Secchi transparencies at the open water station Green-1 (taken by the Level II volunteer) ranged between 2.4 and 5.0 m from May through October, averaging 3.7 m (Figure 3), while student measurements (Level I) made throughout the year from the dock ranged between 2.1 and 4.3 m, averaging 3.2 between May – October and 3.3 m over the entire year.

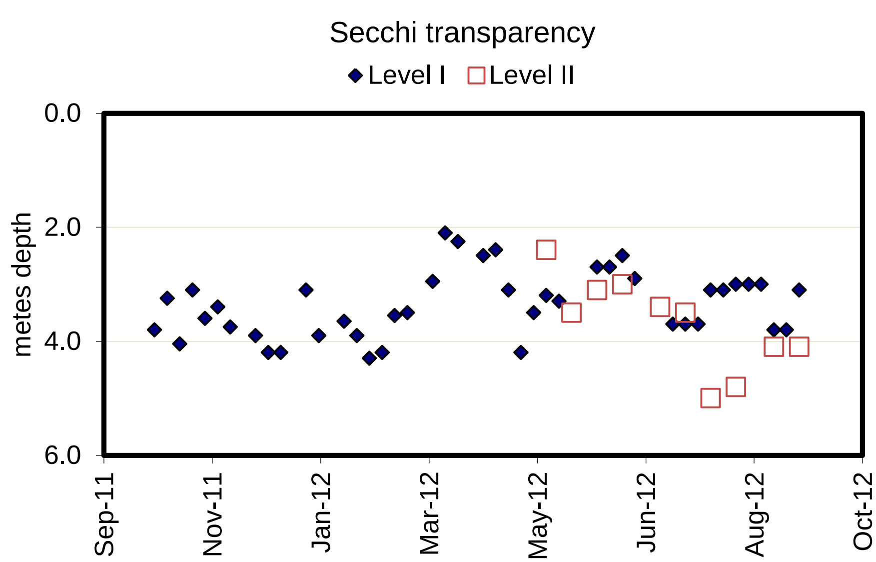

Figure 3. WY 2012 Green-1 (Level II) and East Dock (Level I) Secchi transparency

The differences between the volunteer readings at the sampling site and the student readings at the dock may be understood by taking into account the many different factors that can bias a Secchi measurement, such as direction and strength of wind, different visual acuities, glare, depth of water at the site, and location on the lake. In some years, the shallow water column at the dock site limited the depth to which the Secchi disk could be lowered, and the depth recorded sometimes may have been a minimum value because the Secchi reached the lake bottom before it disappeared from view. Therefore, the students' readings might be viewed as a minimum estimation of the average value. In addition, prevailing winds are from the southwest and often algae will be blown shoreward by the wind, concentrating in the area of the dock, which increases the turbidity of the water and lowers the Secchi depth. Given these challenges, the agreement between the open water and dock measurements of Secchi depth is fairly good overall.

At station Green-1 (Level II) surface water temperatures from May through October ranged between 16 and 23.5 degrees Celsius with an average temperature of 19.2 (Figure 4). At the East Dock, temperatures over the entire year ranged from 4.0 to 23.0 degrees Celsius with an annual average of 13.8 (57 degrees Fahrenheit), while the May – October average was 20.2 (68 degrees F). Green Lake is in the lower third for summer maxima recorded among the lakes monitored by King County in 2012.

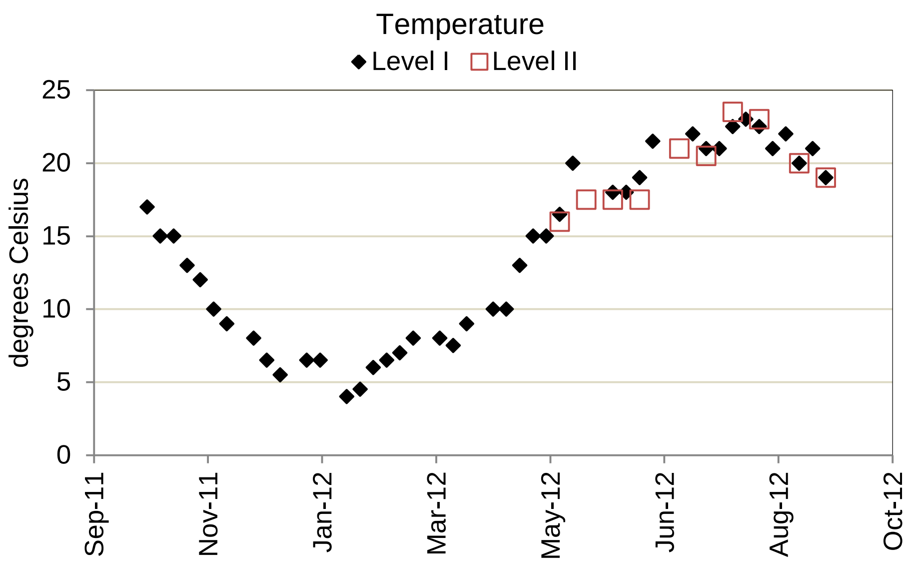

Figure 4. WY 2012 Green-1 (Level II) and East Dock (Level I) Temperatures

Mean summer water temperatures during the time period that Green Lake has been monitored have varied from year to year, but show no statistically strong trend toward change (Figure 5).

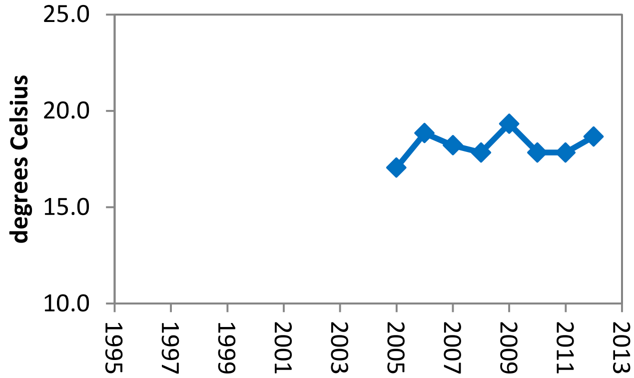

Figure 5. Mean May – October 1m water temperatures for Green Lake at the mid-lake station (Green-1) over the last 8 years

Nutrient and Chlorophyll Analysis

Phosphorus and **nitrogen** are naturally occurring elements necessary in small amounts for both plants and animals. However, a variety of activities associated with residential development can increase concentrations of these nutrients beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is generally the nutrient in least supply relative to the biological demand; this means that algal productivity is often limited by the amount of phosphorus available for growth and reproduction. Increases in phosphorus concentrations can lead to more frequent and dense algae blooms – a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by species that can produce toxins.

The alum treatment in 2004 at Green Lake reduced the amount of phosphorus available by binding it tightly, and forming a floc layer that kept P in the sediment thus keeping it from being available for growing algae. Since 2005, water quality samples collected by volunteers between May and October have been analyzed for total phosphorus (TP) and total nitrogen (TN) concentrations at one meter depth, with deeper water also sampled twice during the period of measurement each year.

At Green Lake-1 neither TN nor TP varied greatly, remaining fairly constant through the sampling period (Figure 6). Maximum TN was 0.387 mg/L with a minimum of 0.270, while maximum TP was 0.016 mg/L with a minimum of 0.010. Please note that the units for TN are 10 times higher than for TP on the chart in Figure 6, so when values for the two parameters are close together on the graph, nitrogen is 10 times more abundant by weight.

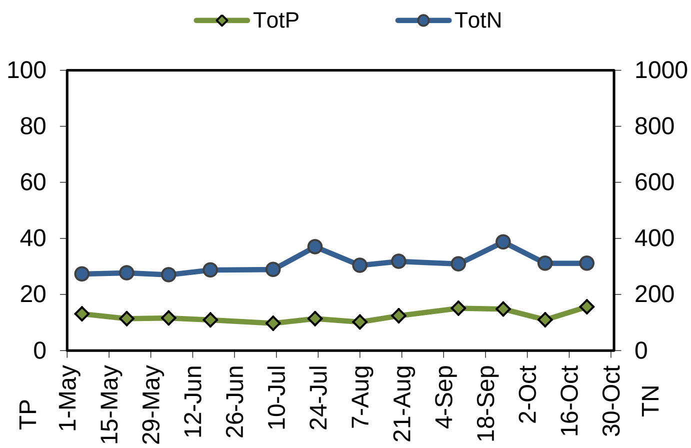

Figure 6. 2012 Green-1 Total Phosphorus and Total Nitrogen in ug/L.

The ratio of nitrogen (N) to phosphorus (P) can be used to determine if nutrient conditions are favorable for the growth of cyanobacteria (bluegreen algae) that will allow it to dominate the community and might impact beneficial uses of the lake. When N:P ratios are lower than an approximate value of 25, certain cyanobacteria species can dominate the algal community due to their ability to fix nitrogen directly from the air.

From May – October in 2012 total phosphorus and total nitrogen ratios ranged from 19.9 to 32.5 with an average of 25.6, with five dates having an N:P ratio below 25 and most values near 25 (Figure 7). This suggests that the nutrient conditions through most of the sample period may have been favorable for nuisance cyanobacterial success in the lake, although weather conditions and the low concentration of available phosphorus overall might limit the size of the population.

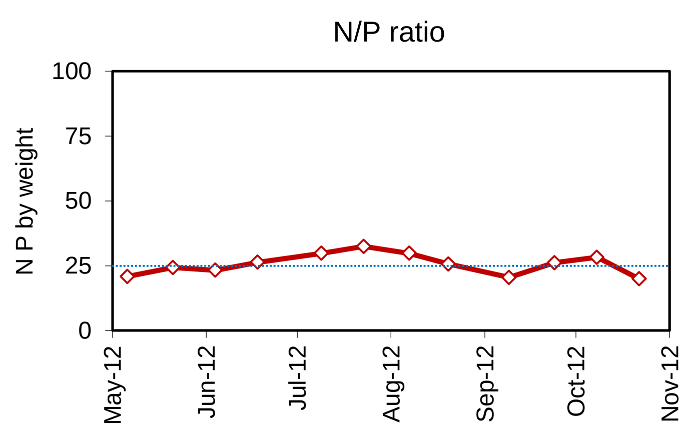

Figure 7. 2012 Green-1 Total Phosphorus and Total Nitrogen Concentrations

Chlorophyll *a* remained at consistently low values with small variations through the sampling period at the mid-lake station Green-1, consistent with low phosphorus availability (Figure 8). Pheophytin (degraded chlorophyll) was also low throughout the sampling season, although on a number of dates it was only slightly lower than chlorophyll a. The shallow nature of the lake coupled with a relatively large fetch probably leads to some sediment re-suspension and recirculation of detritus containing degraded chlorophyll from the sediments.

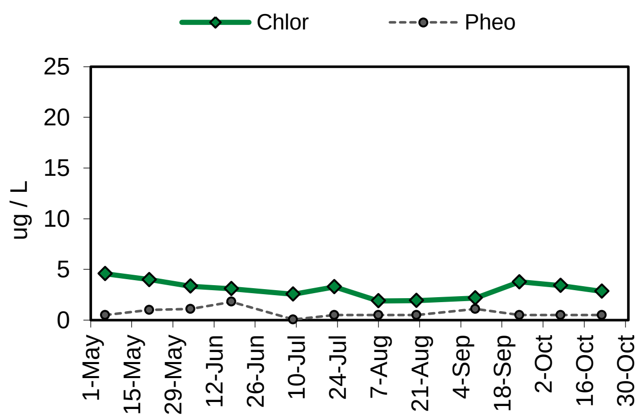

Figure 8. 2012 Green-1 Chlorophyll *a* and Pheophytin concentrations

Algal toxicity

Although the mid-lake station samples had low concentrations of chlorophyll a between May and October, there were periods in 2012 when cyanobacteria accumulated against the shorelines, pushed by waves and wind. This is because cyanobacteria are buoyant and can be easily moved across expanses of water to produce scum accumulations, even when there is no "bloom" in the sense of an overall large abundance of algae in a lake.

There were minor and major episodes of visually determined scum formation that were tested in 2012 for toxins by submitting samples to the Washington Department of Ecology Algae Program. An accumulation of scum was reported in winter 2012 that produced a trace of microcystin, though well below the provisional state guideline of 6 ug/L (Table 1).

No further scums were reported until late September, when a scum was sampled along the shoreline of the small cove north of the boast rental office and dock by the East Green Lake swimming beach (Table 1). The level of microcystin in this sample was considerably above the provisional state guideline, and more samples were taken as soon as the value was validated. The data from October 2nd showed that outside of scum accumulations, microcystin values were quite low, but the highly concentrated algae within the scums could pose health and safety risks.

Weekly samples were taken at points around the lake from then until three weeks in a row produced values below detection.

Table 1. Green Lake cyanobacterial toxicity sampling under the WDOE algae program in 2012. All values in ug/L. The < symbol signifies below the minimum detection limit. Samples above the recreational guideline **(6 ug/L)** are marked in red.

Date	Microcystin	scum sample	Location
2/8/12	0.067	YES	NE cove by dock
9/28/12	34.4	YES	NE cove by dock
10/2/12	0.169	no	Aquatic Center - SW shoreline
10/2/12	0.177	no	NE cove by dock -outside scum
10/2/12	128	YES	patchy scum off East beach
10/2/12	419	YES	NE cove by dock - inside scum
10/9/12	25.6	YES	NE cove by dock
10/9/12	0.406	no	NE cove by dock
10/16/12	0.495	no	beach by Densmore drain
10/16/12	1.63	no	foam on Duck Island beach
10/16/12	0.055	no	Aquatic Center - SW shoreline
10/23/12	0.062	no	Aquatic Center - SW shoreline
10/24/12	29.3	YES	Duck Island beach
11/5/2012	0.08	no	Aquatic Center - SW shoreline
11/5/2012	73	YES	W of Duck Island beach
11/13/2012	<0.05	no	Aquatic Center - SW shoreline
11/13/2012	<0.05	no	NE cove by dock
11/20/2012	0.05	no	Aquatic Center - SW shoreline
11/20/2012	<0.05	no	NE cove by dock
11/26/2012	<0.05	no	Aquatic Center - SW shoreline
11/26/2012	<0.05	no	NE cove by dock

While substantial lake-wide toxic algae blooms are not occurring in Green Lake at this time, relatively small amounts of toxin-producing algae can accumulate downwind and form concentrated patches along shorelines. These patches may pose a localized health threat to dogs drinking heavily from a scum containing toxin-producing algae. Pet owners should be aware of this and keep pets away from patches of scum accessible from the shore.

A picture of the scum during the fall period (Figure 7) shows that the accumulation was discontinuous along the shoreline.

Figure 7. Accumulation of algae along the north shoreline in Fall 2012.

The King County swimming beach program included weekly samples at the west swimming beach for the bluegreen algal toxins microcystin and anatoxin-a as well as fecal coliform bacteria concentrations, from late May through September in 2012. All spring and early summer toxin results were below the minimum detection level at the swimming beaches, but from August on small hits of microcystin were detected. All of the microcystin levels were below 1 ug/L (Washington State Department of Health recreational guidelines are 6 ug/L), but this does suggest that conditions at Green Lake can host some limited cyanobacterial growth and toxins are being produced, albeit at low levels. King County swimming beach data can be viewed at: http://green.kingcounty.gov/swimbeach/

Water column profiles

Profile data (Table 2) from Green-1 indicate that the lake was fairly well mixed thermally throughout the sampling season. Nitrogen is often found in the form of ammonia (NH_3) in deep water when oxygen becomes depleted during periods of thermal stratification, thus when present, it can be used as an indicator of low oxygen concentrations when oxygen cannot be measured directly because of lack of equipment or resources. However, no increases in ammonia (NH_3) were found in the deep water in the spring profile samples, and although during late summer there seemed to be a slight increase in ammonia, it is not enough to suggest that anoxic conditions became established in the lake. The lack of temperature differences between shallow and deep water supports the idea that thermocline development was most likely transitory, as it generally has been in the past in Green Lake.

Concentrations of phosphorus in the deep water remained roughly equivalent to shallow depths, showing that any phosphorus released from the sediments under the oxygenated conditions was likely mixed quickly through the entire water column. Chlorophyll a data indicated that low concentrations of algae were equally distributed through the water column through the season.

Table 2. Green-1 Profile Sample Analysis Results. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 is in absorption units. Sample values below minimum detection level (MDL) are marked in bold, red with the MDL value.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Green	5/21/12	3.5	1	17.5	4.0	1	0.277	**0.005**	0.0114	**0.0020**	0.0329	39.7
Green			3	17.3	4.2	**0.5**	0.290		0.0129			
Green			6	17.0	4.2	1.3	0.301	0.015	0.0162	**0.0020**		
Green	8/20/12	4.8	1	23.0	1.9	**0.5**	0.318	0.011	0.0124	**0.0020**	0.020	40.3
Green			3	23.0	1.9	**0.5**	0.287		0.0148			
Green			6	23.0	1.9	1.1	0.315	0.008	0.0215			

NOTE: In Table 2, <MDL stands for "below minimum detection level" of the analytical method.

The low values for UV254 indicate that the water of the lake is fairly clear and not colored by organic substances. The total alkalinity values show that the water in the lake is relatively soft, in the mid range for lakes that have been measured in King County, and only lightly buffered against pH change.

TSI Ratings

A common method of tracking water quality trends in lakes is by calculating the "trophic state index" (TSI), developed by Robert Carlson in 1977. TSI values predict the biological primary productivity of the lake (phytoplankton biovolume). The TSI values can be based on water clarity (Secchi), concentrations of total phosphorus (TP), or chlorophyll *a*. The Index relates to three categories of productivity:

- *oligotrophic* (low productivity, below 40 on the TSI scale - low in nutrient concentrations, small amount of algae biovolume);
- *mesotrophic* (moderate productivity, between 40 and 50 on TSI scale – moderate nutrient concentrations, moderate amount of algae biovolume); and
- *eutrophic* (high productivity, above 50 – high nutrient concentrations, high level of algae biovolume).

At station Green-1 in 2011 the TSI-Chlorophyll and TSI-Secchi indicators were in the lower range of mesotrophy, higher than the value for TSI-TP (Figure 8). These values have varied a little over time since alum treatment in 2004, with the TSI-Secchi apparently the most stable since then. The phosphorus and chlorophyll TSI values have been more variable from year to year, but overall the indicators since alum treatment in 2004 have placed Green Lake in the lower range for mesotrophy.

Values used for calculating the TSI values for the years 1995 – 1996 and 2000 were provided by Kevin Stoops of the Seattle Parks Department and Rob Zisette of Herrera Environmental consultants. It should be noted that while 1995 – 1996 were sampled throughout the summer, values for 2000 were based on 3 sample dates from May through July of that year. While this makes direct comparability somewhat problematic, May – July are typically months that have good conditions for algae growth and are also a time in which much recreational activity is occurring.

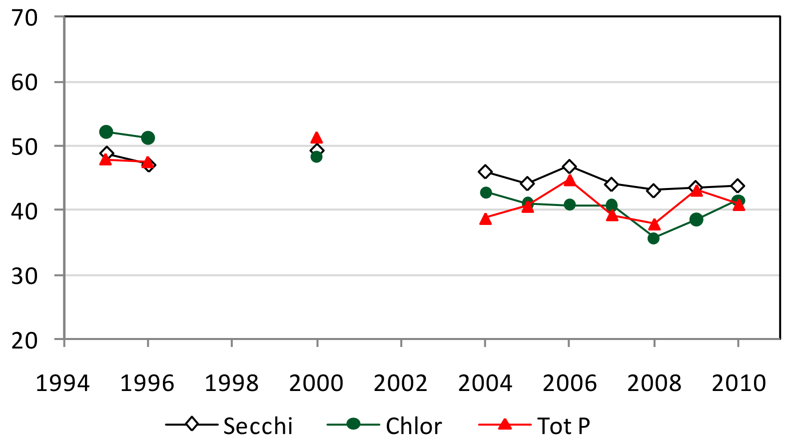

Figure 8. Green Lake-1 Trophic State Indicators

In addition to the volunteer monitoring conducted described in this report, the following additional monitoring data were collected at Green Lake during WY 2012 by other agencies and programs:

- King County Swimming Beach Monitoring (http://green.kingcounty.gov/swimbeach/)
- SPU continuous stage measurements (available from Seattle Public Utilities upon request)
- Water quality monitoring by Seattle Parks department (available upon request)
- Algae scum sampling done by the Washington State Department of Ecology (see Table 2) (https://fortress.wa.gov/ecy/toxicalgae/InternetDefault.aspx)

Conclusions and Recommendations

Based on monitoring data, water quality in Green Lake has been relatively stable over the period measured since the alum treatment in 2004. The success of the second alum treatment, coupled with previous diversion actions of storm water away from the lake, has probably had much to do with the stable nutrient status of the lake over the last eight summers.

The low N:P ratios indicate that nutrient conditions are sometimes favorable for cyanobacterial (bluegreen algae) growth. To date, the overall low levels of available phosphorus have likely kept major blooms from forming, but low TN:TP ratios suggest that at times nitrogen could be limiting as well.. Monitoring of nutrient and chlorophyll concentrations should be continued to assess future conditions and to verify trends, in particular to continue to document the longevity of the effect of the 2004 alum treatment.

Because alum does not impact nitrogen, it may be assumed that nitrogen inputs and external phosphorus inputs might remain steady, as long as theere are no major changes to the current inputs such as stormwater systems that feed the lake. Therefore, sharp increases in biovolumes of cyanobacteria capable of fixing nitrogen from the air could signal that more phosphorus from the sediments is becoming available for algae growth. If this appears to be occurring, new or different management strategies should be sought and evaluated at that time.

Algae accumulations have been observed at places and times other than the monitored swimming beaches during summer. These should continue to be sampled, including submitting bloom or scum samples to the Washington State Department of Ecology's Toxic Algae Monitoring Program to determine whether or not the cyanobacteria present in the lake are producing toxins . This will allow officials to identify health and safety hazards, thus allowing Seattle Parks and Seattle King County Public Health to take protective actions to safeguard the public.